

Kunal Garg

Postdoctoral scholar

Electrical and Computer Engineering
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Research Interests

Finite- and Fixed-time stability theory for safe and robust distributed control and optimization, Multi-agent systems and control, Constrained control synthesis using optimization methods, Continuous-time optimization, Hybrid and Switched Systems

Experience

Postdoctoral scholar

Department of Electrical and Computer Engineering, University of California, Santa Cruz

Advisor [Prof. Alvaro Cardenas](#) and [Prof. Ricardo Sanfelice](#)

Project Secure and Resilient Design of Internet of Battlefield Things

Education

Graduate Studies

PhD, Aerospace Engineering, University of Michigan, Ann Arbor (April 2021)

Advisor [Prof. Dimitra Panagou](#), Aerospace Engineering

Thesis Advances in the Theory of Fixed-time Stability with Applications in Constrained Control and Optimization [[Thesis](#)] [[Defense video](#)]

GPA 4.00 on a scale of 4.00

M.S.E., Aerospace Engineering, University of Michigan, Ann Arbor (April 2019)

GPA 4.00 on a scale of 4.00

Undergraduate Studies

B. Tech, Indian Institute of Technology, Bombay, India (April 2016)

Major Aerospace Engineering with Honors

Minor Computer Science and Engineering

GPA 9.32 on a scale of 10.00 (Silver Medalist)

Publications

Published Journal Articles

1. **Garg, K.**, Cosner, R. K., Rosoliya, U., Ames, A. D., and Panagou, D., “[Multi-rate Control Design under Input Constraints using Fixed-Time Barrier Functions](#)”, IEEE Control Systems Letters, Vol. 6, pp 608-613, 2022.
2. Breeden, J., **Garg, K.**, and Panagou, D., “[Control Barrier Functions in Sampled-Data Systems](#)”, IEEE Control Systems Letters, Vol. 6, pp 367-372, 2022.
3. Baranwal, M., **Garg, K.**, Panagou, D., and Hero, A. “[Distributed Fixed-Time Economic Dispatch under Time-Varying Topology and Uncertain Information](#)”, IEEE Control Systems Letters, Vol. 5, No. 4, pp 1183-1188, October 2021.
4. **Garg, K.**, and Panagou, D., “[Finite-Time Stability of Hybrid Systems with Unstable Modes](#)”, Frontiers in Control Engineering, Vol. 2, August 2021.
5. **Garg, K.**, and Panagou, D., “[Fixed-Time Stable Gradient Flows: Applications to Continuous-Time Optimization](#)”, IEEE Transactions on Automatic Control, Vol. 66, No. 5, pp 2002-2015, May 2021.
6. **Garg, K.**, and Baranwal, M., “[CAPP: Continuous-time Accelerated Proximal Point Algorithm for Sparse Recovery](#)”, IEEE Signal Processing Letters, Vol. 27, pp 1760-1764, September 2020.
7. **Garg, K.**, and Panagou, D., “[Finite-Time Estimation and Control for Multi-Aircraft Systems under Wind and Dynamic Obstacles](#),” AIAA Journal of Guidance, Control and Dynamics, Vol. 42, No. 7, pp 1489-1505, July 2019.

Submitted Manuscripts

8. **Garg, K.**, Arabi, E., and Panagou, D., “Fixed-time Control Under Spatiotemporal and Input Constraints: A Quadratic Program Based Approach”, *Automatica*.
9. **Garg, K.**, Baranwal, M., Gupta, R., and Benosman, M. “Fixed-Time Stable Proximal Dynamical System for Solving Mixed Variational Inequality Problems”, *IEEE Transactions on Automatic Control*.

In Preparation

10. **Garg, K.**, Baranwal, M., Hero, A., and Panagou, D., “Fixed-time Distributed Optimization under Time-Varying Communication Topology”.

Peer-reviewed Conference Papers

1. **Garg, K.**, and Panagou, D., “Finite-Time Stabilization of Switched Systems with Unstable Modes,” 60th IEEE Conference on Decision and Control, 2021, to appear.
2. **Garg, K.**, and Panagou, D., “Robust Control Barrier and Control Lyapunov Functions with Fixed-Time Convergence Guarantees,” Annual American Control Conference, New Orleans, Louisiana, May 2021. **ACC Talk**
3. **Garg, K.**, and Panagou, D., “Characterization of Domain of Fixed-time Stability under Control Input Constraints,” Annual American Control Conference, New Orleans, Louisiana, May 2021. **ACC Talk**
4. Black, M., **Garg, K.**, and Panagou, D., “A Quadratic Program based Control Synthesis under Spatiotemporal Constraints and Non-vanishing Disturbances,” 59th IEEE Conference on Decision and Control, Jeju Island, South Korea, December 2020.
5. Usevitch, J., **Garg, K.**, and Panagou, D., “Strong Invariance Using Control Barrier Functions: A Clarke Tangent Cone Approach,” 59th IEEE Conference on Decision and Control, Jeju Island, South Korea, December 2020.
6. **Garg, K.**, Baranwal, M., and Panagou, D., “A Fixed-Time Convergent Distributed Algorithm for Strongly Convex Function in a Time-Varying Network,” 59th IEEE Conference on Decision and Control, Jeju Island, South Korea, December 2020.
7. **Garg, K.**, Arabi E., and Panagou, D., “Prescribed-time convergence with input constraints: A control Lyapunov function based approach,” Annual American Control Conference, Denver, Colorado, July 2020. **ACC talk**
8. Arabi E., **Garg, K.**, and Panagou, D., “Safety-Critical Adaptive Control with Nonlinear Reference Model Systems,” Annual American Control Conference, Denver, Colorado, July 2020.
9. **Garg, K.**, and Panagou, D., “Control-Lyapunov and Control-Barrier Functions based Quadratic Program for Spatio-temporal Specifications,” 58th IEEE Conference on Decision and Control, Nice, France, December 2019.
10. **Garg, K.**, and Panagou, D., “Hybrid Planning and Control for Multiple Fixed-Wing Aircraft under Input Constraints,” **Best Student Paper Finalist**, AIAA Science and Technology (SciTech) Forum, San Diego, CA, January 2019.
11. Usevitch, J., **Garg, K.**, and Panagou, D., “Finite-Time Resilient Formation Control with Bounded Inputs,” 57th IEEE Conference on Decision and Control, Miami, Florida, December 2018.
12. **Garg, K.**, and Panagou, D., “New Results on Finite-Time Stability: Geometric Conditions and Finite-Time Controllers,” American Control Conference, Milwaukee, Wisconsin, June 2018.
13. **Garg, K.**, and Panagou, D., “A Robust Coordination Protocol for Safe Multi-Agent Motion Planning,” AIAA Science and Technology (SciTech) Forum, Kissimmee, Florida, January 2018.
14. **Garg, K.**, Han, D., and Panagou, D., “Robust Semi-Cooperative Multi-Agent Coordination in the Presence of Stochastic Disturbances,” 56th IEEE Conference on Decision and Control, 2017, Melbourne, Australia, December 2017.

Talks and seminars

Institute for Robotics and Intelligent Machines, Georgia Institute of Technology [Feb 2021]

Title Fixed-time Stability in Multiagent Control under Input Constraints

Title Prescribed-time control under spatiotemporal and input constraints: A QP based approach

Research Experience

Current Research Work

2021- Secure and Resilient Design of Internet of Battlefield Things

Position Postdoctoral Scholar

Collaborators Prof. Alvaro Cardenas, Prof. Ricardo Sanfelice

Description The objective is to have networks of autonomous and non-autonomous system consisting of drones, robots, sensors, and biometric wearable devices that are communicating and sharing information securely. Key results include:

- Notion of temporal security pertaining to safety and convergence under attacks on system input or output during a finite length of interval

2017-21 From High-Level Task Specifications to Geometric Control via Lyapunov Abstractions

Position Graduate student research assistant

Collaborators Prof. Dimitra Panagou, Dr. Ehsan Arabi

Description The goal of this research project is to narrow the existing gap between high-level discrete task planning and low-level continuous control in complex multi-agent missions within a control-theoretic framework. Key results include:

- QP based control design for constrained non-linear dynamical system using for complex missions involving STL based specification such as safety and fixed-time convergence
- Robust control scheme for multi-agent scenario involving safety and convergence requirements under additive disturbances and estimation uncertainties
- Multiple-Lyapunov function based conditions for Finite-time stability of Switched and Hybrid systems under arbitrary switching and unstable subsystems

2019-21 Fixed-time Optimization

Position Graduate student research assistant

Collaborators Prof. Dimitra Panagou, Prof. Alfred Hero, Dr. Mayank Baranwal, Dr. Rohit Gupta

Description In this project, we are exploring gradient based schemes to compute the optimal solution of optimization problems in a fixed time. Key results include:

- Fixed-time converging gradient flow based optimization schemes for constrained and unconstrained convex optimization, and minmax problems
- Novel fixed-time scheme for distributed optimization under relaxed assumptions on the objective functions; applications include large-scale SVM, economic dispatch
- Fixed-time stable proximal dynamical systems for nonsmooth optimization problems

Past Research Work

2016-18 Trajectory Prediction of Multiagent Systems in Obstacle Environment

Collaborators Prof. Dimitra Panagou

Description We aim to develop robust, Lyapunov-based coordination protocols that achieve collision-free motion for multiple agents in a distributed fashion, in the presence of state and measurement uncertainties. Key results include:

- Distributed multi-agent collision avoidance algorithm under system uncertainties and partial information for quadrotors; implementation on Gazebo
- Switched system based multi-agent motion planning algorithm for fixed-wing aircraft

Undergraduate Research Experience

Bachelor's Thesis, IIT Bombay

[2015-16]

Supervisor Dr. Aditya Paranjape, Department of Aerospace Engineering, IIT Bombay

Title Flutter Mitigation using Active Feedback Control
 Visiting International Research Student [Summer 2015]
 Supervisor Prof. Homayoun Najjaran, School of Engineering, University of British Columbia, Okanagan
 Title Controller Development for Underactuated Camera Gimbal Design
 Research Intern [Summer 2014]
 Supervisor Dr. Vipin Kumar, Senior Scientist, Central Scientist Instruments Organization, Chandigarh
 Title Development of Attitude Estimation Algorithm for Attitude and Heading Reference System

Teaching Experience

U-M Graduate Teaching Certificate

Awarded by UMich Center for Research on Learning & Teaching in Winter 2021 [Description](#)

Graduate Student Instructor

[Winter 2019] EECS 562: Nonlinear Systems and Control

Instructional Aid

[Winter 2020] AEROSP 740: Special Topics on Multi-agent Control

[Winter 2018] EECS 562: Nonlinear Systems and Control

[Fall 2017] AEROSP 584: Navigation and Guidance of Aerospace Vehicles

Mentorship and Leadership Experience

2018-20 Supervising undergraduate and graduate students

- Description
- Guided Master's student in developing RRT based motion planning algorithm for non-holonomical system
 - Guided Master's students for research projects related to fixed-wing multi-agent motion planning; developed and implemented controller on quadrotor test-bed using ROS and MATLAB
 - Supervised three undergraduate students for Summer Undergraduate Research Program on development of Gazebo simulation environment for visualization of motion planning algorithms

2016-19 **President and Treasurer**, Indian Students Association, University of Michigan

Vision To help Indian students feel like home away from home

- Description *Led a team of 8 members to help new students with their admission and transition process*
- Organized large scale events to make Indian students feel home
 - Arranged airport pickups, temporary accommodation and shopping trips for 100s of new admits

2015-16 **Head**, Department Academic Mentorship Program, IIT Bombay

Vision To assist academically weak students cope up

- Description *Led a team of 21 mentors to guide the department students in academic endeavours*
- Conducted tutorial sessions for weak students before exams to improve their performance
 - Closely monitored student performance and guided them in planning their course load
 - Actively raised students' concerns among faculty members while acting as a link between the faculty and the students.

Awards and Honors

Richard and Eleanor Towner Prize for Distinguished Academic Achievement	2021
Professor Pierre T. Kabamba Award for excellence in control systems	2021
Student Travel Grant for IEEE 59th Conference on Decision and Control	2020
Student Travel Grant for IEEE Annual American Control Conference	2020
Best Student Paper Finalist, AIAA Guidance, Navigation and Controls Conference	2019
Tau Beta Pi member: Initiated at TBP-Michigan Gamma chapter in December	2017
Institute Silver Medal, Department Rank 1, IIT Bombay	2016

References

Prof. Dimitra Panagou

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Prof. Ilya Kolmanovsky

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Prof. Dennis Bernstein

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